TITLE: Evaluating the Impact of Environmentally Friendly Cleaners on System Readiness

EVALUATING THE IMPACT OF ENVIRONMENTALLY FRIENDLY CLEANERS ON SYSTEM READINESS

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Abstract: Federal, state and local regulations limiting the use, storage and disposal of hydrocarbon-based cleaning solvents have led to the uncontrolled replacement of solvents with environmentally friendly products. The Army and other defense agencies rely on these solvents to maintain unique, mission critical systems and materiel and the replacement of hydrocarbon solvents has resulted in use, approval and compatibility issues. The U.S. Army Environmental Center (USAEC) and Aberdeen Test Center (ATC) have developed an Alternative Cleaner Compatibility and Performance Evaluation Program to survey user needs, validate alternative cleaner performance, consolidate lessons learned and provide a web based dissemination, review and evaluation tool. The test criteria were developed based on input from the technical community, the test community and the user community. A cooperative program between cleaner manufacturers and USAEC/ATC is currently in progress to evaluate currently available cleaner technology. The objective of this paper is to discuss the current status of the alternative cleaner testing and efforts to develop a universal test protocol that will provide the DOD community with the data necessary to make wise decisions concerning the replacement of hydrocarbon based cleaners. The culmination of the process will provide a user-friendly mechanism to facilitate implementation of environmentally friendly replacement products and technologies.

Key Words: Aqueous cleaners, cleaning, environmentally friendly products, hydrocarbon-based solvents, material compatibility, product validation, system readiness.

Introduction

Background: The U.S. Army Environmental Center (USAEC) and the U.S. Army Aberdeen Test Center (ATC) are currently leading an effort to investigate the appropriateness of using aqueous based cleaners during general maintenance and repair operations. These efforts were prompted due to complaints from field components that alleged corrosion of equipment after continuous operational use of aqueous based cleaning systems. USAEC was given the task of executing a project for the purpose of

substantiating or disproving these performance claims. There are several issues driving the search by installation and field components to replace hydrocarbon-based cleaning solvents including many federal, state and local regulations that limit the use, storage and disposal of hydrocarbon-based cleaning solvents and in many cases significant cost savings. Unfortunately, the Army and other defense agencies rely on these solvents to maintain unique, mission-critical systems and materiel and these systems may be compromised by indiscriminate use of unqualified cleaners.

Problem: To put the problem into context, in 1998 more than 40 Army installations sought money for alternative cleaning systems through the Pollution Prevention Investment Fund (P2IF). The total FY99 funding request for these projects was $1.1 M for a total net annual cost avoidance for $642 K (payback 2.74 years). While this shows initiative and a commitment to stewardship, many of the installations have bought (or are trying to buy) products that have not been fully qualified for use on Army equipment. It also must be kept in mind that this is only one funding source and only in the Army. The true magnitude of the problem throughout the various branches of the armed forces is not well documented. The problem is compounded by the fact that many of these products have GSA contract numbers and are listed as "environmentally friendly" replacements in Defense Logistics Agency (DLA) catalogs. Many purchasing organizations are unaware of the requirement to request approval for changes in cleaner systems from the respective commodity manager.

Solution: The purpose of the effort initiated by USAEC was to provide a mechanism to evaluate aqueous-based cleaners for applicability to U.S. Army and DOD maintenance and repair activities. To achieve this goal USAEC and ATC coordinated the development of a comprehensive aqueous based cleaner test protocol. The protocol is unique because it is the first comprehensive test protocol known to have been developed for this purpose with input by stakeholders from the aviation, small arms, and tank, automotive and armaments communities. The initial test protocol development included Army stakeholders, however, ongoing efforts have included input from stakeholders in the Navy, Air Force and Marines. The goal of the effort has expanded to include the development of DOD test protocol for aqueous cleaners.

Current Status: The protocol has been implemented on a limited basis to test several cleaners to specific requirements of specific Army activities. The lessons learned from these small-scale applications have been incorporated into the final draft protocol currently being circulated to stakeholders within all branches of the armed services. USAEC and ATC are currently leading a multi-agency initiative to comprehensively test several cleaning products and gather data that can be used to make procurement and usage decisions. The agencies involved will use a through screening process to decide which products to put through the full range of performance tests. Testing will be jointly funded; solvent manufacturers will pay for the test on their specific products, while the Army will maintain overall test capabilities and purchase materials needed to conduct the test.

Test protocol

General: The cleaner performance test protocol includes three sub-test areas: Cleaner Evaluation; Material Compatibility; and Service Test. The issues of greatest concern to the technical user community were the material compatibility of the aqueous based cleaners with the materiel being maintained and the performance characteristics of the cleaners. Other areas of concern during protocol development were product characteristics, worker health and safety issues and environmental impacts. The criterions were developed based on military objectives and materiel. The evaluation methodologies were, however, based on national and international standards. Standard test methods were used wherever possible to promote broader acceptance and applicability of the test results for both the DOD maintenance and manufacturing communities.

Protocol Development: The development of the test protocol addressed three tasks in the following order: criteria development, selection of materials, and selection of test methods. The cleaner protocol was developed to satisfy a diverse set of criteria from the user community, the materials developer community and the scientific community. This set of criteria provided the basis for developing a protocol that would address the issues of all concerned parties. The criteria fell into three categories of; general product characteristics related to worker safety and environmental impact, performance of the product and material compatibility issues with regard to current solvent applications. The interested parties also identified those materials for evaluations that they felt were the most problematic in their operations. The final step of developing the protocol was to identify appropriate test methods to access the performance of the cleaners against the established criteria. The bulk of the test methods selected were standard test methods from recognized organizations like the American Society of Testing and Materials (ASTM) or Society of Automotive Engineers (SAE). In a few instances military standards were used to address issues specifically related to military materiel or missions. The protocol was reviewed and approved by all interested parties. Table I shows the resulting test matrix of test methods. Table II shows a list of the materials currently incorporated into the various sub-tests. These tables are attached at the end of the paper. Both of the tables represent the methods and materials that cover the concerns of the Army stakeholders who were the primary parties involved in the current draft of the protocol.

Materials Compatibility

Overview of Testing to Date: The products examined to date have excelled in areas of worker health and safety. They also performed well against the environmental impact and characteristic criteria that support the operational cost benefits of the product. These results confirmed the expected results since these are the primary advantages of environmentally friendly products. There have been some issues with cleaner performance. In some cases even though the cleaners cleaned off the contaminant materials, they left a residue on the materiel that adversely impacted the test results and maintenance procedures. In the area of material compatibility problems were identified

during corrosion testing of some of the metals as well as degradation of some plastics and coatings.

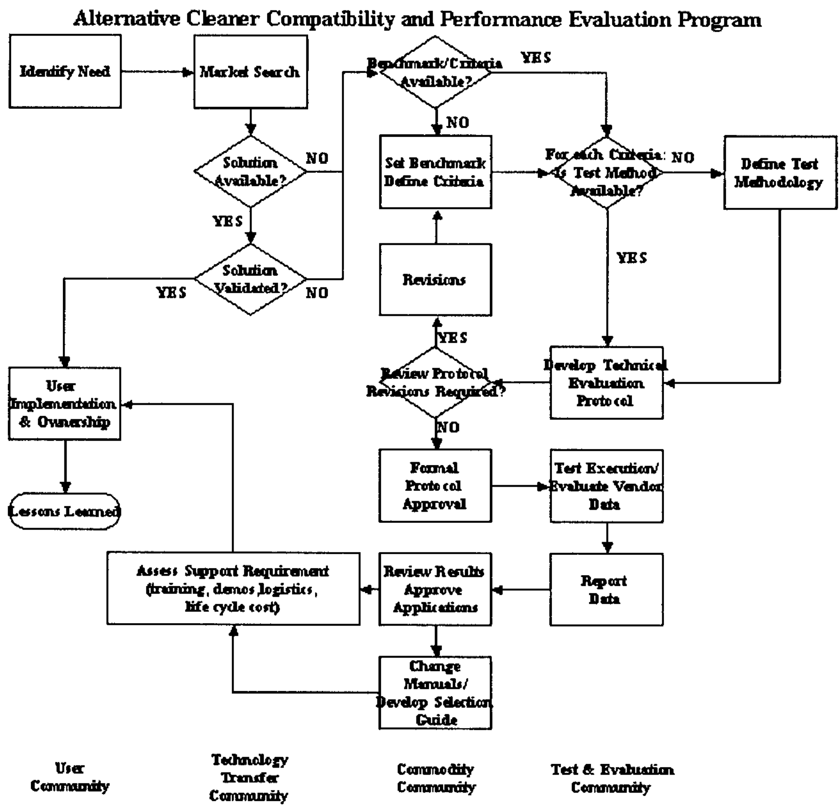

Figure 1. Flowchart representation of environmentally friendly product evaluation protocol development process from identification of need to user implementation and ownership.

Problems & test modifications: The objective of the protocol is to provide technical data on aqueous cleaners, which can be used to determine the cleaner's applicability to U.S. Army maintenance and repair activities. During test method selection every effort was made to use test methods that would simulate actual operation environment conditions for the tested cleaners. Towards this end some of the standard test methods were modified to provide test conditions that more accurately reflected operating environments. During the initial test program several problems, shortcomings and improvements were identified. In some cases the criteria were vague and difficult to use in evaluation or did not allow for a full indication of the test results. An example of this

was the total immersion corrosion criteria that stated a weight loss criterion and referenced a visual inspection but provided no pass/fail criteria for the visual inspection. As a result instances occurred where a specific combination of cleaner and material resulted in significant general corrosion, however, the weight loss criteria was not exceeded. Another challenge was the procurement of the materials. Some of the material alloys identified are costly and difficult or impossible to procure in the relatively small quantities required for testing. In some cases it was difficult to identify an appropriate test method to evaluate properties such as cleanliness or odor. All these issues need to be addressed keeping in mind the requirement of not only developing a technically sound protocol but also a test matrix that can be completed in a reasonable period of time for a reasonable investment of funds. One improvement that has already been incorporated into the protocol is a phasing of the test matrix. The test methods were grouped to provide maximum return on the dollar early in testing. Each phase consists of group of test methods that are conducted simultaneously and the performance of each cleaner is evaluated at the completion of each phase. This protects the investment of the manufacturer by identifying potential problems quickly utilizing relatively inexpensive test methods. A cleaner that fails a critical sub-test during a given phase of testing is not required to continue and thereby saves the cost of the later phases of testing.

Following is a discussion of several of the test methods utilized and any modifications applied as well as representative results.

Total Immersion: The total immersion corrosion caused by the manufacturer's suggested working concentration of the cleaner is determined using ASTM F-483-90, Standard Test Method for Total Immersion Corrosion Test for Aircraft Maintenance Chemicals. In addition to the requirements of ASTM F-483-90 the testing is conducted at the operating temperature for the cleaner. In many cases for aqueous cleaners the operating temperature is 100-105 ^{o}F. Problems in past testing have included excessive weight loss for Mg and Cd-plated 4340 samples. In some cases significant general corrosion was noted in test specimens that met the weight loss criteria. This is an example of an area where inspection criteria need to be better defined.

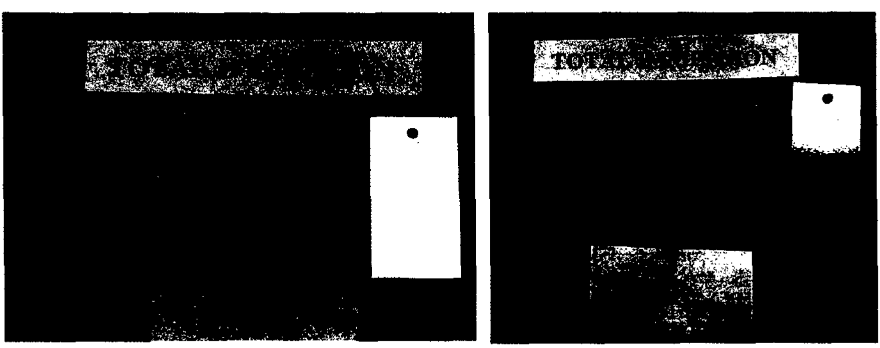

Figure 2. Total immersion test specimens of maraging C-250 and Cu UNS 36000 after 168 hours of exposure in an aqueous based alternative cleaner.

Sandwich Corrosion: The sandwich corrosion caused by the manufacturer's suggested working concentration a cleaner product was determined using ASTM-F-1110-90, Standard Test Method For Sandwich Corrosion Test. The criterion in the Test Protocol states, "The manufacturer's suggested working concentration shall not cause a corrosion rating greater that two (2) on any test panel and the manufacturer's suggested working concentration shall not cause a corrosion rating greater than P-D-680 (II)" (for zinc-phosphated 4340 coupons only). ASTM F-1110-90 states, "Any corrosion in excess of that shown by 'reagent water group' shall be cause for rejection." Any panel with pitting was given a severity rating of 4. Some cleaning products tested to date have had difficulty meeting the criterion for sandwich corrosion for the following materials: PH 13-8 Mo stainless steel, maraging C-250 steel, AISI/SAE 4340 steel, magnesium AMS 4377, and zinc-phosphated 4340 steel alloy (figure 2).

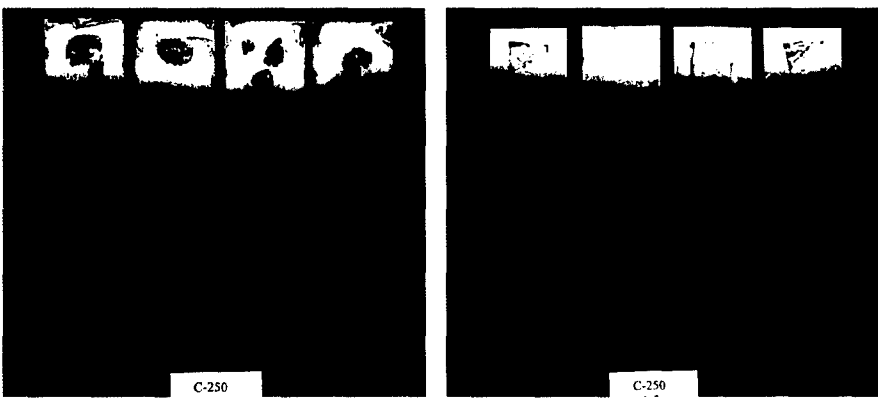

Figure 3. Sandwich corrosion maraging C-250 steel test specimens exposed to the test cleaner (left) and reagent water (right).

Effects on Painted Surfaces: The criteria is that the manufacturer's suggested working concentration of the cleaning compound shall not cause streaking, discoloration, blistering or a permanent decrease in film hardness of more than one (1) pencil hardness level on any painted surfaces. The effect of the manufacturer's suggested working concentration of the cleaning compound on the painted surfaces is determined using ASTM F-502-93 (app C, ref 15), Standard Test Method for Effects of Cleaning and Chemical Maintenance Materials on Painted Aircraft Surfaces, modified by the Test Protocol. One of the previously tested products did not meet the criterion for effects on painted surfaces for the MIL-P-14105 heat-resistant paint. There was also a slight color change on the exposed end of the MIL-C-46168 aliphatic polyurethane, single-component topcoat panels, which indicated marginal compatibility with this coating. One of the topcoat products specified was unavailable and it has been recommended that a replacement be selected by the interested technical POC.

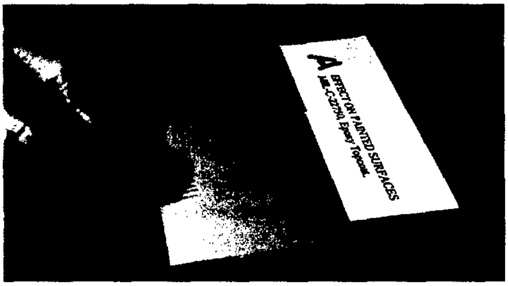

Figure 4. Testing for hardness changes in paints as a result of exposure to aqueous based cleaners.

Effects on Acrylic Plastics and Polycarbonate Plastics: The stress-crazing effect that the manufacturer's suggested working concentration of the test cleaner product has on acrylic plastics and polycarbonate plastics is determined using ASTM F-484-83, Standard Test Method for Stress Crazing of Acrylic Plastics in Contact with Liquid or Semi-Liquid Compounds. The criteria states that the manufacturer's suggested working concentration shall not cause stress crazing or staining of polycarbonate plastics. This test has been a challenge to set up for since it is difficult finding suppliers of these specific plastics in reasonable amounts for a single test. These materials are normally sold in large sheets and are relatively expensive. It has proved to be a valuable screening test since crazing of the polycarbonate plastic has been observed within 30 minutes of exposure to a subject cleaner.

Next Steps

Alternative Compatibility and Performance Evaluation Program: The program efforts at this stage are proceeding along two paths. USAEC and ATC are preparing to test a number of cleaner candidates based on the current protocol. The funding to purchase test materials and specimens has been provided through government sources, primarily through P2IF. The participating manufacturers will pay for each phase of testing as a lump sum and based on the results of each phase they may or may not continue to participate in subsequent phases. The methods included in each phase were chosen to provide maximum return on investment earlier in the testing. A program kick-off meeting to be attended by all interested parties is planned for February 2001. The data results produced by this testing will be passed along to the commodity managers and materiel developers so that they can make decisions regarding the use of a given cleaner. ATC's role is that of an independent test organization. ATC will provide the test services and technical evaluation of each cleaner relative to the test criteria. Commodity managers and materiel developers who have both the expertise and authority to make these decisions will make decisions regarding product use.

The second aspect of the ongoing aqueous based solvent project is the continued refinement of the protocol itself. The protocol is a living document at this point and one

of the main thrusts is to involve a maximum number of technical organizations within the DOD system in order to include their input. The ultimate goal is to develop a universal test protocol that will provide all members of the DOD community with the data they need to make wise decisions concerning the replacement of hydrocarbon based cleaners. Currently personnel within the Navy, Air Force and Marines are reviewing the protocol and the Navy has already provided input about additional test methods and materials that they will need added to the protocol to cover their unique requirements.

Related Efforts Concerning Other Categories of Environmentally Friendly Products: One of the lessons learned throughout the process of identifying the requirements and developing the protocol for evaluating aqueous based cleaners relates to the whole arena of environmentally friendly replacement products. There are many products throughout the government procurement system that are being billed as environmentally friendly alternatives to approved products. There is a separate DLA catalog for these products and many of these products are being offered for procurement in the same manner as the hydrocarbon based solvent replacements, without approval for use from the appropriate agencies. There is no standard mechanism for evaluating the claims of these products or the impact of these products on DOD materiel. A proposal has been submitted and is currently being evaluated recommending that the protocol development process used for this project be used as a strawman for the process of evaluating other categories of replacement products. In general, a small test protocol development team would be assembled at ATC and operate under the direction of a DOD working group involving appropriate technical personnel from commodity managers, materiel developers and testing communities. The working group or the funding source would identify a priority list of those product categories that will require evaluation. The working group would solicit and identify the requirements (criteria) for a given product category, review the test methodology (test protocol) and provide final approval of the test protocol. The development team at ATC will develop a draft test protocol for each product category using the working group requirements as the metrics for the product evaluation, and national and international test methods, when available, to ensure product vendor acceptance of the protocol.

Conclusion

The Alternative Solvents Substitutes Performance Validation Test Protocol addresses many of the concerns that both the user community and the material developer communities have identified. Thanks to the Alternative Solvent Substitution Performance Validation Program, the Army and other DOD agencies will be able to better preserve readiness, save money and avoid bad decisions by knowing which alternative cleaning products meet its stringent requirements for performance, soldier safety and environmental compliance. Vendors and manufacturers will have a clearly defined and accepted process for validating their products for possible defense procurement. Using this program as a model, performance validation protocols for other environmentally friendly product replacements can be developed and implemented.

Table I. Test Matrix of Methods Currently Incorporated into the Alternative Cleaner Compatibility and Performance Evaluation Test Protocol.

Test Matrix - Alternative Cleaner Compatibility & Performance Evaluation Program		
Test Title	**Test Method**	**Requesting Agency**
Flash point	ASTM-D-92-90	All
pH	ASTM-E-70-90	All
Heat stability	MIL-C-87937B	AMCOM
Toxicity	AR 40-5	AMCOM/All
Biodegradability	40CFR Part 796.3100	ATC
Non-volatile residue	MIL-C-87937B	AMCOM
Cleaning efficiency	ASTM-F-22-65	AMCOM
Constituents	MIL-C-29602	All
Appearance	MIL-C-29602	AMCOM
Volatile organic chemicals	EPA Method 8206A	All
Water break free	ASTM-F-22-65	AMCOM
Cold stability	MIL-C-87937B	AMCOM
Fluorescent penetration Inspection	Level(IV) Inspection	AMCOM
Drying point	ASTM-D-86-96	TACOM
Relative solvency	TACOM Method	TACOM
Non-volatile residue (TACOM)	ASTM-E-1131-93 Mod	TACOM
Coating adhesion	Fed Std Method 6301.2	AMCOM
Effects on painted surfaces	ASTM-F-502-93	AMCOM
Total immersion corrosion	ASTM-F-483-90	AMCOM
Sandwich corrosion	ASTM-F-1110-90	AMCOM
Hydrogen embrittlement	ASTM-F-519-93	AMCOM
Effects on unpainted surfaces	ASTM-F-485-90	AMCOM
Effects on polymide wire	MIL-C-87937B	AMCOM
Effects on acrylic plastic	ASTM-F-484-83	AMCOM
Rubber compatibility	ASTM-D-2240-95	AMCOM
Effects on polysulfide sealant	MIL-C-87937B	AMCOM
Effects on polycarbonate plastic	ASTM-F-484-83	AMCOM
Effects on bonding	ASTM-D-3167-93	AMCOM
Stress corrosion	ASTM-G-44-94	AMCOM
Effects on sealant peel strength	AMCOM Procedure	AMCOM
Copper corrosion	ASTM-D-130-94	TACOM
Steel corrosion	ASTM-D-130-94 Mod	TACOM
Bimetallic couple corrosion	Fed Std 791C	ARDEC
Effects on storage	ATC Test Method	ARDEC

Table II. Listing of the Materials Currently[1] Incorporated into Alternative Cleaner Compatibility and Performance Evaluation Test Protocol.

Metals

—Aluminum, 2024-T3 (Anodized per MIL-A-8625, Type I)

—Aluminum, 2024-T3 (Conversion Coat per MIL-C-5541)

—High strength steel AM-355 CRT

—High strength steel PH 13-8

—High strength steel Maraging C-250

—Aluminum 7075-T6

—Titanium 6AL-4V

—Steel 4340

—Aluminum 7075-T6 (Alclad)

—Magnesium AMS-4377 (surface treatment MIL-M-3171, Type III)

—Cadmium plated steel (4340), **ASTM-F-519-93 plating method**

—Nickel plated steel (4340)

—Steel 1020

—Inconel 718-Bar

—Ti-6AL-4V-Bar

—Zinc phosphated steel (4340), per DOD-P-16232F

—Manganese phosphated steel (4340), per DOD-P-16232F

—Copper alloy UNS C36000

—Copper, hard tempered, cold-finished, 99.9 % purity

Paints

—Primer coating, MIL-P-23377 epoxy

—Primer coating, MIL-P-85582

—Top coat MIL-C-85285, polyurethane, High solids

—Top coat MIL-C-22750, Epoxy

—Top coat MIL-C-46168, Aliphatic, polyurethane, single component

—Top coat MIL-L-46159, Lacquer, acrylic, low reflective

—Top coat MIL-P-14105, Heat resistant

—Top coat MIL-E-52891B, Enamel, lusterless,
zinc phosphate, styrenated alkyd type

Other materials

—Acrylic plastic MIL-P-5425, Finish A

—Acrylic plastic MIL-P-8184, Finish B

—Acrylic plastic MIL-P-25690

—Polycarbonate plastic MIL-P-83310

—Polymide wire

—Rubber, Type SAE 3204

—Rubber, Type SAE 3209

—Polysulfide sealant MIL-S-81733, Type 1

—Polysulfide sealant MIL-S-8802, Type 1

Note: 1. Additional materials will be added as required to support the requirements of the Navy, Air Force and Marines.